Automating Seismic Risk Mitigation
For Nonstructural Building Components
The Design/Build Approach

Project Management
- Data Acquisition
- Risk Assessment
- Project Design
- Project Management

Fabrication

Installation

Engineering
- Restraint Design
- Quality Assurance
- Documentation

Seismic Systems Integration

MCEER

TerraFirm
Project Management

Activity
• Field Data Acquisition
• Risk Assessment
• Project Design
• Project Management
• Fabrication
• Installation

Software
SSI FIELD
CSA S832
SSI CONTRACT
Corecon, Project Kick Start
Corecon, SHOP CAD
Project Kick Start

Engineering

• Performance Based Engineering
• Automated Engineering
• Mitigation Design
• Quality Assurance
• Documentation

Software
Mathcad
SSI SANE
CAD
SSI MONITOR
SSI DOCS
Typical Investments In Building Construction

* Eduardo Miranda, PhD, Department of Civil & Environmental Engineering, Stanford University, 2003.
Economic Losses

Niigata Earthquake – October 23, 2004

Sanyo Electric Niigata Semiconductor Fab Plant

- Plant damage: $177 million USD
- Lost inventory: $44 million
- Restoration: $260 million
- Business interruption: $356 million

Total Losses: $837 million

Yoshiko Hara, EE Times December 21, 2004 (2:33 PM EST)
The Tyranny Of Large Numbers

- OFCs/room: 30
- Rooms: 200
- Facilities: 2,500
- Total restraint points: 15,000,000

What Must Be Done

- Identify, locate & assess OFC
- Engineer a mitigation solution
- Install the restraint system
- Document the process
Data Acquisition from Nonstructural Equipment
Starting with adding a new project, company, facility contacts etc. in the office before setting out for data collection.
Building level information is where we start to get specific with parameters for design. Listed here are Canadian code variables. You will see how we can adjust the available lists to suit California later.
This illustrates information recorded in project level attachments. Attributes are editable. Any file can be added here including floor plans, maps, correspondence, and photos.
This screen manages files stored locally and on SSI Web. You can retrieve projects from the web server to work on or submit updated projects from your local machine. This is where the collaboration starts.
USER MASTER LISTS

Select List

Total List Items: 5

List Items:

- Item 1
- Item 2
- Item 3
- Item 4
- Item 5

CURRENT PROJECT LISTS

Project Name: Sample 1
Select List

Total List Items: 5

List Items:

- Item 1
- Item 2
- Item 3
- Item 4
- Item 5

ADD/EDIT LIST ITEM

Description: Certificate

OK | Cancel

List manager for customizing the items available in pull down menus. Typical items expected for a site visit should be pre-entered in the office to save time on site. Specific lists for types of rooms or facilities can be managed for later use. This creates standard item names.
Items stored in Master list can be added in one click to project lists.
Now that custom lists are set up and ready to go the item entry screen is next. I want to show you the most recent screens for this and will, but for now here are the older screen shots:
Selecting source for image capture. This will be your digital camera connected via USB.
Floors and rooms can be added on the fly from here, or you can flip back to the list management screen without losing your place in the items database.
<table>
<thead>
<tr>
<th>Item #</th>
<th>Tag #</th>
<th>Description</th>
<th># Units</th>
<th>Restraint</th>
<th>Gap</th>
<th>Overturning</th>
<th>Location</th>
<th>Vulnerability Score</th>
<th>Property Protection</th>
<th>Total Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>Genset-a Emergency Generator</td>
<td>1</td>
<td>10</td>
<td>10</td>
<td>0</td>
<td>1</td>
<td>7.1</td>
<td>1</td>
<td>42.6</td>
</tr>
<tr>
<td></td>
<td>Floor</td>
<td>Room</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Parkade Plaza Level Generator room</td>
<td>4</td>
<td>1</td>
<td>5</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td>43</td>
</tr>
<tr>
<td></td>
<td>Comments</td>
<td>250KW / 312KVA, Generator only weighs 825Kg, Spring mounts not seismically rated. Motor is 6 cylinder Iveco Alto.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>Silencer</td>
<td>1</td>
<td>10</td>
<td>10</td>
<td>0</td>
<td>1</td>
<td>7.1</td>
<td>1</td>
<td>42.6</td>
</tr>
<tr>
<td></td>
<td>Floor</td>
<td>Room</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Parkade Plaza Level Generator room</td>
<td>3</td>
<td>1</td>
<td>5</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td>43</td>
</tr>
<tr>
<td></td>
<td>Comments</td>
<td>Silencer 22.5&quot; diam. X 4’11” long. Inside piping runs 5’9” turns 90 deg, runs 4’10” and exits through wall. No restraint.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>Exhaust Pipe (outside)-a</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0.8</td>
<td>1</td>
<td>4.8</td>
</tr>
<tr>
<td></td>
<td>Floor</td>
<td>Room</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Parkade Parkade entrance caged area</td>
<td>3</td>
<td>1</td>
<td>5</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Comments</td>
<td>Piping is hung with short rods and penetrates walls at either end, sufficient restraint.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>Cooling Air Plenum-a</td>
<td>1</td>
<td>10</td>
<td>10</td>
<td>0</td>
<td>1</td>
<td>7.1</td>
<td>1</td>
<td>42.6</td>
</tr>
<tr>
<td></td>
<td>Floor</td>
<td>Room</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Parkade Plaza Level Generator room</td>
<td>4</td>
<td>1</td>
<td>5</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td>43</td>
</tr>
<tr>
<td></td>
<td>Comments</td>
<td>No existing restraint. Vertical support only.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Project Planning & Scheduling

### Project: OR Mounts - Installation Schedule

<table>
<thead>
<tr>
<th>#</th>
<th>Task Name</th>
<th>Assignments</th>
<th>Start</th>
<th>Finish</th>
<th>Minutes</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Preparation for Construction</td>
<td>Lindsay Minto, Rob Thomas, Mark de Koning</td>
<td></td>
<td></td>
<td></td>
<td>detailed tasks</td>
</tr>
<tr>
<td>2</td>
<td>Construction Start-up meeting with client and site manager (on site)</td>
<td>Lindsay Minto, Rob Thomas, Mark de Koning, Getinge Installers, Electrician, Data</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Submit order &quot;float&quot; for fasteners and other common items</td>
<td>Rob Thomas</td>
<td></td>
<td></td>
<td></td>
<td>Standard float list for typical jobs should be developed</td>
</tr>
<tr>
<td>4</td>
<td>Prepare tool list for mobilization</td>
<td>Rob Thomas</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Rent Hepa Vacuum, screw jacks, lifting device, and shopping material.</td>
<td>Rob Thomas</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Shop to approve tool list, acquire additional tools as required</td>
<td>Rob Thomas</td>
<td></td>
<td></td>
<td></td>
<td>Forward looking view for special core drill bit sizes and lengths is required. Review plans to determine.</td>
</tr>
<tr>
<td>7</td>
<td>Finalize fabrication of mounting posts with Getinge mounting plate as template</td>
<td>Rob Thomas</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Fabricate and bundle work (labelled with location or reference number)</td>
<td>Rob Thomas</td>
<td></td>
<td></td>
<td></td>
<td>Reference numbers to be marked on restraint with weld bead as necessary.</td>
</tr>
<tr>
<td>9</td>
<td>Mobilize tools and materials</td>
<td>Rob Thomas, Matt Duffie</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Ship material to site (first or all bundles)</td>
<td>Rob Thomas</td>
<td></td>
<td></td>
<td></td>
<td>Have everything ready day before, loaded on truck and ready to roll.</td>
</tr>
<tr>
<td>11</td>
<td>Schedule tentative interim engineering inspection</td>
<td>Mark de Koning</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Toolbox safety meeting (division manager to host for site staff)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Prepare agenda in advance</td>
</tr>
</tbody>
</table>
Seismic Fitting Fabrication.
Seismic Fitting Fabrication.
Installation

Robotic tape drive located on a raised access floor.
Installation - Infection Control
Automated Engineering - OFC Type

Please select an **OFC type** and then click Next, or just click Next to search all **OFC types**.

- Nonstructural equipment with cylindrical shape or circular x-section.
- Nonstructural equipment with cubic shape or rectangular x-section.
- Structurally similar nonstructural equipment or nonstructural equipment with a frame shape.
- Nonstructural equipment or OFC's with architectural functions and artworks.
# Seismic Mitigation Engineering

## Detail Design Identification of OFC (CSA S832 categories)

<table>
<thead>
<tr>
<th>Categories</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Architectural (functional)</td>
<td>Canopies, porches</td>
</tr>
<tr>
<td></td>
<td>Suspended ceilings</td>
</tr>
<tr>
<td></td>
<td>Partitions</td>
</tr>
<tr>
<td>Building Service (operational)</td>
<td>Heating, ventilation</td>
</tr>
<tr>
<td></td>
<td>Piping systems</td>
</tr>
<tr>
<td></td>
<td>Electrical equipment</td>
</tr>
<tr>
<td></td>
<td>IT/Telecom systems</td>
</tr>
<tr>
<td>Building Contents (operational)</td>
<td>Office equipment</td>
</tr>
<tr>
<td></td>
<td>Medical equipment</td>
</tr>
</tbody>
</table>

- **Categories**
  - Architectural
  - Building Service
  - Building Contents
- **Example**
  - Canopies, porches
  - Suspended ceilings
  - Partitions
  - Heating, ventilation
  - Piping systems
  - Electrical equipment
  - IT/Telecom systems
  - Office equipment
  - Medical equipment
CLASSIFICATION OF OPERATIONAL AND FUNCTIONAL COMPONENTS (OFCs) OF BUILDINGS IN TERMS OF THEIR SHAPE, FUNCTION, RESTRAINT, AND DETAIL OF CONNECTION IN ORDER TO FACILITATE HIGH VOLUME SEISMIC RISK MITIGATION ENGINEERING
## Classification Methodology

### Seismic Analysis of Nonstructural and Equipment - SANE 2005

#### Nonstructural equipment with cylindrical shape or circular X section

<table>
<thead>
<tr>
<th>Code</th>
<th>Type</th>
<th>Definition</th>
<th>Seismic Restraint Detail</th>
<th>Seismic Force Calculation</th>
<th>Seismic Restraint Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>101</td>
<td>102</td>
<td>Vertical cylinder on desk top</td>
<td>#1 #2 #3 #4 #5</td>
<td>IBC 1997</td>
<td>Mathcad Design Codes and Other References</td>
</tr>
<tr>
<td>103</td>
<td>104</td>
<td>Vertical cylinder on legs</td>
<td>#1 #2 #3 #4 #5</td>
<td>NBCC 1995</td>
<td>Mathcad Design Codes and Other References</td>
</tr>
<tr>
<td>105</td>
<td>106</td>
<td>Vertical cylinder on base</td>
<td>#1</td>
<td>NBCC 2005</td>
<td>Mathcad Design Codes and Other References</td>
</tr>
<tr>
<td>107</td>
<td>108</td>
<td>Horizontal cylinder supported by wall</td>
<td>#1</td>
<td>Mathcad Design Codes and Other References</td>
<td></td>
</tr>
<tr>
<td>109</td>
<td>110</td>
<td>Horizontal cylinder on legs</td>
<td>#1 #2 #3 #4 #5</td>
<td>Mathcad Design Codes and Other References</td>
<td></td>
</tr>
</tbody>
</table>

---

Seismic Systems Integration

[Link to TerraFirm Website]

Prepared by Terra Firm Engineering Division

ami@terrafirm.ca

View Readme

Install Acrobat Reader
Seismic Mitigation Engineering Detail Design

Mathcad Design Template


The 1997 UBC specifies a design lateral force $F_p$ for nonstructural components as

$$F_p = \left( a_p C_a R_p \right) \left( 1 + \frac{3h}{h_p} \right) W_p$$

but $F_p$ need not be greater than

$$F_p = 4C_a I_p W_p$$

nor less than

$$F_p = 0.7C_a I_p W_p$$

where

- $a_p$ = component amplification factor in accordance with
- $C_a$ = seismic coefficient
- $I_p$ = importance factor
- $R_p$ = component response modification factor
Seismic Mitigation Engineering Detail Design

Mathcad Design Template

Input Data

$W_p = 100000$

$h_w = 200$

$h_h = 300$

Select Seismic Source Type based on the UBC 1997 16-U table

- [ ] Seismic Source Type A
- [x] Seismic Source Type B
- [ ] Seismic Source Type C
- [ ] N/A (Default)

Select Closest Distance to Known Seismic Source

- [ ] Less than or Equal to 1.25 miles
- [ ] Equal to 3.1 miles
- [ ] Greater than or Equal to 6.2 miles
- [ ] N/A (Default)
Seismic Mitigation Engineering Detail Design
Mathcad Design Template

Select the Nonstructural components from category 1 to 4 (See table 16.0 UBC 1997)

- 1A(1) OF (ap=2.5, Fp=3.0)
- 1A(3) OF (ap=1.0, Fp=3.0)
- 1A(3) OF (ap=1.0, Fp=3.0)
- 1B OF (ap=2.5, Fp=3.0)
- 1C OF (ap=1.0, Fp=3.0)

J. Elements of Structures
A. Walls including the following:
   (1) Unbraced (unreinforced) precast.
   (2) Exterior walls at or above the ground floor and parapets above their centers of gravity.
   (3) All interior-bearing and nonbearing walls.
B. Parapets (except when faced by an extension of the structural frame).
C. Connections for prefabricated structural elements other than walls. See also Section 1532.2

- 2A OF (ap=2.5, Fp=3.0)
- 2B(1) OF (ap=2.5, Fp=3.0)
- 2B(2) OF (ap=1.0, Fp=3.0)
- 2C OF (ap=2.5, Fp=3.0)
- 2D OF (ap=2.5, Fp=4.0)
- 2E OF (ap=1.0, Fp=3.0)
- 2F OF (ap=1.0, Fp=3.0)
- 2G OF (ap=1.0, Fp=3.0)
Seismic mitigation engineering. **Example 1**

**Cylindrical OFC**

<table>
<thead>
<tr>
<th>Code</th>
<th>Type</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>103</td>
<td><img src="image1.png" alt="Image" /></td>
<td>Medical gas tanks</td>
</tr>
</tbody>
</table>

Photos of OFC **before** installation of Seismic Restraint
Seismic mitigation engineering. Example 1

Cylindrical OFC
Seismic mitigation engineering. Example 2

Cubical OFC

<table>
<thead>
<tr>
<th>Code</th>
<th>Type</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>202</td>
<td>Fume Hood</td>
<td></td>
</tr>
</tbody>
</table>

Photos of OFC after installation of Seismic Restraint
Seismic mitigation engineering. Example 2

Cubical OFC

Seismic Systems Integration
**Seismic mitigation engineering. Example 3**

**Cubical OFC**

<table>
<thead>
<tr>
<th>Code</th>
<th>Type</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>205</td>
<td>Microscope</td>
<td>in Operating Room</td>
</tr>
</tbody>
</table>

Photo of OFC before installation of Seismic Restraint
Seismic mitigation engineering. Example 3
**Photos of OFC after installation of Seismic Restraint**

<table>
<thead>
<tr>
<th>Code</th>
<th>Type</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>205</td>
<td>Microscope</td>
<td>in Operating Room</td>
</tr>
</tbody>
</table>
## Seismic Mitigation Engineering

### Identification of OFC (Terra Firm Method.)

#### Table 4. Different types Architectural OFCs

<table>
<thead>
<tr>
<th>Code</th>
<th>Type</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>401</td>
<td>![Acoustical Ceiling Icon]</td>
<td>Acoustical Suspension Ceiling and Fixtures</td>
</tr>
<tr>
<td>402</td>
<td>![Totem Pole Icon]</td>
<td>Totem poles</td>
</tr>
<tr>
<td>403</td>
<td>![Building Cladding Icon]</td>
<td>Building claddings</td>
</tr>
<tr>
<td>404</td>
<td>![Partition Wall Icon]</td>
<td>Partition walls</td>
</tr>
<tr>
<td>405</td>
<td>![Chimney Icon]</td>
<td>Chimneys</td>
</tr>
</tbody>
</table>
### Seismic mitigation engineering

**Example 5**

**Architectural OFC**

<table>
<thead>
<tr>
<th>Code</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>401</td>
<td>![Image of Acoustical Suspension Ceiling and Fixtures]</td>
</tr>
</tbody>
</table>

**Example**

- Acoustical Suspension Ceiling and Fixtures

**Photos of OFC before installation of Seismic Restraint**
Seismic mitigation engineering. Example 5
Architectural OFC
Seismic mitigation engineering. Example 5
Architectural OFC

<table>
<thead>
<tr>
<th>Code</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>401</td>
<td></td>
</tr>
</tbody>
</table>

**Example**

- Acoustical Suspension Ceiling and Fixtures

Photos of OFC after installation of Seismic Restraint
Seismic Mitigation Engineering.

A flowchart for the application of the methodology of classification

Restraint Design

Start

Enter the code for the OFC

OFC Identification process

If the restraint drawing is available?

no → Design the required Restraint element and connection components

yes → If modification required?

no → Production of drawings

yes → Completion of modification

Production of final Identification code

Cost estimation of Fabrication and installation for the restraint

End
## SANE-Seismic Analysis of Nonstructural Equipment

Seismic Risk Assessment, Restraint Design, Drawing, and Cost Estimation for Nonstructural Equipment

### Pipe and in fine pump

#### Properties:
- **Pipe size**, number of runs and seismic parameters

<table>
<thead>
<tr>
<th>Code</th>
<th>OD (Pipe diameter)</th>
<th>Pipe’s thickness</th>
<th>Seismic zone</th>
<th>Importance factor</th>
<th>Seismic Coefficient</th>
<th>Rigidity</th>
<th>Amplification</th>
<th>Max number of pipe runs</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1/2</td>
<td>12.70</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>1</td>
<td>3/4</td>
<td>19.05</td>
<td>1.0</td>
<td>1.5</td>
<td>1.5</td>
<td>1</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>1.25</td>
<td>25.40</td>
<td>1.0</td>
<td>1.5</td>
<td>1.5</td>
<td>1</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>1/2</td>
<td>38.10</td>
<td>1.0</td>
<td>1.5</td>
<td>1.5</td>
<td>1</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>1.5</td>
<td>50.80</td>
<td>1.0</td>
<td>1.5</td>
<td>1.5</td>
<td>1</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>1.5</td>
<td>83.50</td>
<td>1.0</td>
<td>1.5</td>
<td>1.5</td>
<td>1</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>76.20</td>
<td>1.0</td>
<td>1.5</td>
<td>1.5</td>
<td>1</td>
<td>2</td>
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<td>7</td>
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<td>101.60</td>
<td>1.0</td>
<td>1.5</td>
<td>1.5</td>
<td>1</td>
<td>2</td>
<td>4</td>
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<tr>
<td>8</td>
<td>6</td>
<td>152.40</td>
<td>1.0</td>
<td>1.5</td>
<td>1.5</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>9</td>
<td>8</td>
<td>203.20</td>
<td>1.0</td>
<td>1.5</td>
<td>1.5</td>
<td>1</td>
<td>2</td>
<td>2</td>
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</tbody>
</table>
Horizontal force requirements from different North American design codes.

<table>
<thead>
<tr>
<th></th>
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<tr>
<td>001</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Applied horizontal force to OFC during an earthquake</td>
<td>$V_p = \frac{0.4 \alpha_s S_{eq} f_p}{R_y} \left(1 + \frac{2 \xi}{\eta} \right) \frac{W_p}{R_y}$</td>
<td>$F_p = \frac{0.35 S_{eq} f_p}{R_y} \left(1 + \frac{2 \xi}{\eta} \right) \frac{W_p}{R_y}$</td>
<td>$F_p = \frac{0.75 S_{eq} f_p}{R_y} \left(1 + \frac{2 \xi}{\eta} \right) \frac{W_p}{R_y}$</td>
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<tr>
<td>003</td>
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</tbody>
</table>

Notes:
- $S_{eq}$ is the equivalent seismic force
- $f_p$ is the peak ground acceleration
- $W_p$ is the weight of the piping system
- $R_y$ is the yield resistance of the structural component
- $\alpha_s$ is the seismic coefficient
- $\xi$ is the damping ratio
- $\eta$ is the period of oscillation

---

Pipe and in line pump

Seismic Systems Integration

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Seismic Restraint for Medical Gas line - Calculation and table

### Seismic Hazard level AA (SHL AA)

- \( V_p/V_s = 1.2 \) (NBCC 1995)
- \( v = 0.4 \) (Zonal velocity ratio)
- \( I = 1.5 \) (Seismic importance factor of the structure)
- \( C_p = 1.0 \) (Seismic coefficient for O&G)
- \( A_r = 1.0 \) (Response amplification factor)
- \( A_x = 2.0 \) (Amplification factor at level X)

### Table 4-1 Seismic Restraint Table for Piping - Multiple Run

<table>
<thead>
<tr>
<th>OD of the pipe runs</th>
<th>Max. No of pipe runs</th>
<th>Restraint spacing</th>
<th>Hanger type</th>
<th>End Clamps type</th>
<th>Castilever type</th>
<th>End Clamps type</th>
<th>Post type</th>
<th>Base plate type</th>
<th>Anchor type</th>
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<tbody>
<tr>
<td>3/4</td>
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<td>30</td>
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<td>38 1/3/1</td>
<td>DN50X5</td>
<td>38 3/8/1</td>
<td>DN50X5</td>
<td>25 Hb X 13 5/8</td>
<td>9 HLT/SLF M 10/20</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td>30</td>
<td>PS100</td>
<td>33 3/8/1</td>
<td>DN50X5</td>
<td>33 3/8/1</td>
<td>DN50X5</td>
<td>25 Hb X 13 5/8</td>
<td>9 HLT/SLF M 10/20</td>
</tr>
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<td>1 1/2</td>
<td>4</td>
<td>30</td>
<td>PS100</td>
<td>20 1/4/1</td>
<td>DN50X5</td>
<td>20 1/4/1</td>
<td>DN50X5</td>
<td>25 Hb X 13 5/8</td>
<td>9 HLT/SLF M 10/20</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>30</td>
<td>PS100</td>
<td>35 1/3/1</td>
<td>DN80X8</td>
<td>35 1/3/1</td>
<td>DN80X8</td>
<td>25 Hb X 13 5/8</td>
<td>9 HLT/SLF M 10/20</td>
</tr>
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<td>3</td>
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</tr>
</tbody>
</table>

**Seismic Restraint for Medical Gas line - Calculation and table**

**Table 4-1 Seismic Restraint Table for Piping - Multiple Run**

**Seismic Hazard level AA (SHL AA)**

- \( V_p/V_s = 1.2 \) (NBCC 1995)
- \( v = 0.4 \) (Zonal velocity ratio)
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Seismic Mitigation Engineering.

Seismic Restraint for Medical Gas line-CAD Blocks and dwgs
Seismic Mitigation Engineering.

Seismic Restraint for Medical Gas line
Documentation

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South Fraser Health Region
Peace Arch Hospital
Seismic Mitigation Program 2001-2002
Final Documentation Package
Prepared by Terra Firm Engineering Group

Seismic Systems Integration

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Documentation

Digital documentation allows for easier presentation and navigation of large volumes of information. PDF format ensures cross platform compatibility.
Proposal documents include planning and budget information along with technical recommendations.
Location information is critical for maintenance, auditing, planning and liability. This key plan map references detailed layouts.
Layouts reference restraint detail drawings that can be looked up using navigation in right hand pane.
Detail drawings included in “as-built” packages help to ensure the systems can be maintained and limit professional liability.
Inevitably, paper documentation will be requested as well and easily be derived from the digital documentation.
Documentation (continued)

Documentation required for building authorities should be automated (as much as possible) and be handled digitally.
Thank You!